Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

THE INFLUENCE OF PROTRACTED AND INTERMITTENT FASTING UPON GROWTH

DR. SERGIUS MORGULIS

In an earlier paper on inanition[1] I pointed out the significance of the period following a prolonged fast in investigating the problem of growth. Prolonged starvation—notwithstanding the exhaustion which it produces—seems to exercise a rejuvenating effect upon the assimilative capacity of the organism, which builds itself up again with surprising rapidity as soon as feeding is resumed. It was also shown there, that the increase in weight of the animal does not necessarily correspond to the quantity of ingested food, being somewhat greater than the latter, which is due to absorption of water from the surroundings. Whereas inanition causes a relatively greater loss of dry substance than of water, it was found that "the effect of resumed feeding (upon the salamander) is to increase the water content more relatively than the dry substance" (p. 213).

Since those results were published I had an opportunity of collecting more material bearing upon this topic. The experiments were made with the salamander *Triton cristatus,* and strengthen my former observations on *Diemyctylus viridescens.* In the subjoined Table *A* the data as to the weight of nine salamanders with the exact amounts of food taken during 7 to 14 days after starvation are summarized. The renewal of feeding after several weeks of privation does not generally proceed smoothly, the animals either taking sick or refusing the food, hence the relapses with the diminution of the body weight which may be seen occasionally throughout the table.

---

[1] Morgulis, S., "Studies of Inanition in its Bearing upon the Problem of Growth," I, *Arch. f. Entw.-Mech.,* Bd. 32, 169–268, 3 plates, 1911.

That the rate of growth is independent of the amount of nutrition is revealed by these experiments in a striking manner; they show rather the reverse, namely, the utilization of the food by the organism according to the need of its tissues and cells. The impulse to grow plays the leading part here, not the quantity of food brought into the digestive organs, and in this respect the growth after starvation has much in common with embryonic growth.

TABLE A

No.	1		2		3		4		5		6		7		8		9	
Days of Feeding	Weight of Animal	Amount of Food in Gms.	Weight of Animal	Amount of Food in Gms.	Weight of Animal	Amount of Food in Gms.	Weight of Animal	Amount of Food in Gms.	Weight of Animal	Amount of Food in Gms.	Weight of Animal	Amount of Food in Gms.	Weight of Animal	Amount of Food in Gms.	Weight of Animal	Amount of Food in Gms.	Weight of Animal	Amount of Food in Gms.
1	0.631	.0450	0.631	.1020	0.755	.1125	1.067	.0580	0.882	.0480	0.889	.0870	0.826	.0920	0.887	.1300	0.821	.0843
2	0.679	.0368	0.749	.0790	0.865	.0565	1.093	.0620	0.917	.0610	1.077	.0870	0.967	.1460	1.084	.1300	0.929	.0736
3	0.729	.0535	0.872	.0490	0.959	.0590	1.102	.0910	1.025	.0610	0.977	.0870	1.169	.1460	0.978	.1300	0.969	.0631
4	0.780	.1215	0.897	.0590	0.973	.0590	1.207	.0570	0.988	.0625	0.937	.1450	1.122	.1270	0.909	.1300	0.969	.0953
5	0.922	.0920	0.977	.0520	0.923	.0525	1.231	.0655	1.041	.0690	1.109	.1450	1.206	.1270	0.909	.1300	1.058	.0662
6	1.077	.0920	0.977	.0520	0.923	.0525	1.251	.0690	1.104	.0540	0.887	.1210	1.146	.1270	0.864	.1520	1.055	.0990
7	0.941	.0920	0.961	.0725	0.919	.0740	1.251	.0690	1.104	.0540	0.978	.0890	1.140	.1270	1.063	.1070	1.000	.0856
8	0.898	.0920	1.001	.1100	1.011	.0930	1.308	.0960	1.037	.1000	1.020	.0890	1.090		1.146	.1070	1.064	.0998
10	0.898	.0920	1.001	.0770	1.011	.1170	1.308	.0800	1.037	.0980	1.020	.0890	1.090		1.146		1.064	
12	0.898	.0920	0.937	.0700	1.107	.0665	1.308	.1070	1.037	.0870	1.020	.0890	1.090		1.146		1.064	
13	0.898	.0920	0.937	.0700	1.107	.0665	1.351	.1030	1.157	.0780	1.020	.0890	1.090		1.146		1.064	
14	0.898	.0920	0.937	.1580	1.107	.1270	1.351	.1030	1.157	.0780	1.020	.0890	1.090		1.146		1.064	
15	1.011	.0920	1.227	.1580	1.227	.1270	1.399	.1030	1.263	.0780	1.120	.0890	1.243		1.200		1.211	

Food offers merely a greater or less scope to the inherent growth-tendency of the organism, and, like so many other factors, may either increase or decrease its effect. It is possible that the reduction in size of the cells, or rather the diminished ratio between cell-body and nucleus, has something to do with the observed processes of intense growth, and that the rejuvenescence of the organism is analogous to the condition in the embryo, where the cell-body is likewise small in relation to its nucleus. There is certainly more than mere superficial resemblance between the two phenomena of growth from the point of view of the protein metabolism. Already in the eighties

Kahan[2] observed that after seventeen days of inanition (when the body had suffered a loss of 31 per cent.) rabbits gained 56 per cent. in weight on a diet even less sufficient than that, which could just maintain them in a state of equilibrium under normal conditions. The retention of protein by the cells, as their principal building material, is greater than usual, and along with it goes the retention of water.

If the growth of the body as regards weight corresponded to the amount of food taken for that period of time, then the coefficient of growth should be equal, $G/F=1$. According as to whether a larger or smaller portion of the food is transformed into body substance, *i. e.*, participates in growth, the coefficient ought to vary from 0 to 1. Furthermore, when the increase in weight of the animal exceeds the quantity of ingested food, the coefficient will rise above 1. In the following Table B we give the records of the body weights for consecutive days, the amount of food ingested and the corresponding coefficient of growth of four animals.

TABLE B

ANIMAL 1

Date	Nov. 3	December							Total for 7 Days
		22	23	24	25	26	27	29	
Body weight in grm. . . .	.910	.631	.679	.729	.780	.922	1.077	.898	
Difference in weight. . . .		−30.6%	+.048	+.050	+.051	+.142	+.155	—	+.267
Amount of food given (in grm.) on previous day.			.0450	.0368	.0535	.1215	.0920	—	.3488
Ratio between increase in weight and amount of food.			1.07	1.36	.95	1.17	1.68	—	.77

---

[2] Kahan, J. A., "Der Einfluss des Hungerns auf das Körpergewicht bei der Auffütterung von Tieren mit einer beschränkten Nahrungsmenge nach einem überstandenen Hunger," *Russ. Medizin*, Nr. 17–19, 1885.

Animal 2

Date	Nov. 8	January							Total for 7 Days
		3	4	5	6	7	8	9	10	
Body weight in grm....	.892	.631	.749	.872	.897	.977	?	.961	1.001	
Difference in weight....		−29.3%	+.118	+.123	+.025	+.080	?	−.016 (?)	+.040	+.370
Amount of food given (in grm.) on previous day......			.1020	.0790	.0490	.0590	.0520	——	.0725	.4125
Ratio between increase in weight and amount of food......			1.16	1.56	.51	1.36	?	?	.56	.89

Animal 3

Date	Nov. 8	January								Total for 7 days
		3	4	5	6	7	8	9	10	
Body weight in grm....	1.064	.755	.865	.959	.973	.923	—	.919	1.011	
Difference in weight....		−29.0%	+.110	+.094	+.014	−.050	—	−.004	+.092	+.256
Amount of food given (in grm.) on previous day......			.1125	.0565	.0590	——	.0525	——	.0740	.3545
Ratio between increase in weight and amount of food......			.98	1.67	.024	?	?	?	1.28	.72

Animal 5

Date	Nov. 14	January								Total for 7 Days
		2	3	4	5	6	7	8	9	
Body weight in grm....	1.140	.882	.917	1.025	.988	1.041	1.104	—	1.037	
Difference in weight....		−22.7%	+.035	+.108	−.037	+.053	+.063	—	−.067	+.155
Amount of food given (in grm.) on previous day......			.0480	.0610	——	.0625	.0690	.0540	——	.2945
Ratio between increase in weight and amount of food......			.73	.177	——	.85	.91	?	?	.53

The animals were weighed both before and immediately after feeding, so that the amount of food consumed could be ascertained accurately by subtracting the former weight from the latter. After twenty-four hours the animals were weighed again, the difference between this weight and that of the previous day giving the growth for twenty-four hours. In some cases the increase is only a fraction of the quantity of food which the animals received; not infrequently, however, it has been even greater than that quantity. In the case of the four salamanders recorded above there are ten out of eighteen determinations, which show an excess of growth over the amount of ingested food. We find that the coefficient of growth never falls below 0.5 (the one instance where it is only 0.24 is obviously accidental); in other words, as regards weight the increase of the body is never equal to less than one half of the quantity of ingested material, and the average coefficient for all four animals for a seven-day period of renewed feeding is 0.73. This fact is particularly significant when we compare it with the condition found in continually fed specimens. In the case of other four control salamanders it was found that the coefficient of growth was only 0.26, *i. e.,* only about 26 per cent. of the food had gone to the building up of the body substance.

When the growth occasioned by a return to a normal diet after a protracted starvation is studied from the point of view of the body dimensions instead of the body weight, it appears that it is exceedingly slow during the first two weeks, showing that during that time primarily the internal organs undergo reparation, the enlargement of the musculature and of the skeleton ensuing subsequently.

Salamanders fed intermittently did not become as heavy nor as large as the control specimens; that is to say, their growth has been retarded from the point of view of both weight and size. The coincidence of the results of measuring both weight and length of the body strengthens our conclusion that frequently repeated starvation affects unfavorably the vitality of the organism. The conclusion concurs with that of Kahan,[3] who subjected pigeons two or three times to hunger, feeding them very abundantly in the periods between, and found that their power of resistance declines with each new experience of starvation.

> Der nach vorhergegangenem Hungern bei unbeschränkter Nahrungsaufnahme aufgefütterte Organismus zeigt die Folgen der früheren Nahrungsentziehung, . . . und bei wiederholter Nahrungsentziehung rascher verfällt, als der gesunde (p. 277).

Seland[4] experimenting with chickens got quite different results. He allowed his birds to reach a state of equilibrium in body weight, when food was withdrawn for periods of one to two days, and then they were again fed. He discovered that the periodically fasting birds grew heavier than the control, although they were actually getting less food. According to von Seland, the increase is not caused by a deposit of fat, but by an accumulation of albuminous material, and the periodic fasting has the effect of making the body heavier, stronger and more solid. Von Seland's assertion, however, regarding the increase in quantity of the albuminous substances lacks the proof of chemical analysis.

We saw in the foregoing that after a period of protracted starvation, when about one fourth of the body weight has been lost, growth is very intense and the per cent. of the consumed food which becomes converted into the substance of the organism is nearly three times as large as in the continually fed salamanders. The impulse to grow determines the degree of utilization of the nutriment, the rate of growth being regulated by the particular state of the cells of the organism, which in turn is probably occasioned by the relation of the nucleus to the cell-body. We shall attempt now to demonstrate this point further by comparing the results obtained for long periods with differently nourished animals. The data which are given in the subjoined tables are so arranged that the number of times when either the starved or the periodically fasting salamanders received food is just one half of the number of feedings of the control specimens for some definite length of time. We take the *number* of feedings which could be obtained from the individual records as indicating the approximate amount of consumed food, since the actual quantities—except in a few instances—have not been measured directly. It is clear, of course, that animals fed *ad libitum* do not always take the same quantity of food, nor is it likely that different animals consume each similar amounts, but in the run of weeks it may be expected that the positive and negative variations will compensate for each other. We may, therefore, accept the *number* of times at which the animals received food as a measure for the *total quantity* of food consumed during a certain period. Furthermore, to make the weights of the different animals comparable with one another they have been computed on the assumption that the initial weight of all animals was one gram.

---

[3] Kahan, J. A., ''Mit Auffütterung abwechselnde akute experimentelle Inanition,'' *St.-Petersburger med. Wochenschr.*, Nr. 30, 275–277, 1886.

[4] V. Seland, ''Ueber die Nachwirkung der Nahrungsentziehung auf die Ernährung,'' *Biol. Centralbl.*, Bd. 7, 145–158, 184–192, 214–224, 246–256, 271–281, 1887.

In Table *C* we have the data of four groups of starved salamanders and of their corresponding controls. The first two groups, each comprising four individuals, are compared at the end of 112 days, during which period the control specimens were fed 96 times, while the others (after 7–8 weeks of complete inanition) were fed 48 times. The ratio between the number of feedings being 1÷0.5, it follows that by the end of 112 days the control animals have probably consumed twice as much food as the starved animals. The final body weight at the close of this period was 3.823 g. and 4.265 g. (1st group), and 3.092 g. and 3.694 g. (2d group), respectively. Taking the mean of these two groups, we get 1÷1.165 as the ratio between the final weights, and 1÷2.45 as the ratio between the daily increase in the control and starved animals. Examining the data of the third and fourth groups where in the course of 84 days the control specimens were fed 72 times and the starved ones only 36 times we encounter practically the same result.

TABLE C

	Group	Control Animals (*A*)	Animals Fed after Protracted Starvation (*B*)	Ratio Between *A* and *B* (*A* = 1)
Number of feedings	i	96	48	1 ÷ 0.5
	ii	96	48	1 ÷ 0.5
	iii	72	36	1 ÷ 0.5
	iv	72	36	1 ÷ 0.5
Body weight (Initial wt. = 1 gr.)	i	3.823	4.265	1 ÷ 1.116
	ii	3.092	3.694	1 ÷ 1.195
	iii	2.557	2.170	1 ÷ 0.849
	iv	3.040	2.635	1 ÷ 0.867
Daily increase in body weight	i	0.029	0.068	1 ÷ 2.345
	ii	0.022	0.056	1 ÷ 2.545
	iii	0.022	0.033	1 ÷ 1.500
	iv	0.028	0.046	1 ÷ 1.643

The fact that in the case of these last two groups the starved individuals have not reached the same weight as the corresponding controls, whereas in the former two groups they even became by one-sixth heavier than the controls, must be attributed to the shorter duration of the feeding-up of these animals. We find thus that a fasting experience enables the organism to attain almost the same weight (or even a greater weight) which animals that did not have such an experience attain, upon half the quantity of their food supply, because the rate of growth after starvation is considerably greater.

We may proceed now in a similar fashion to compare the effect of continual and of intermittent feeding upon the growth of the body. These data are recorded in Table *D*, and are likewise calculated for an initial weight of one gram. The ratio between the number of feedings of these two kinds of animals being 1 ÷ 0.5, the respective body-weights have not become 0.5 of that of the control specimens, but 0.57–0.81; in other words, the intermittently fed animals have increased somewhat more than the control animals would have done with the same quantity of food. Taking the average for all four groups together, we find that the intermittently fed specimens with one half the amount of food reach a little over two thirds of the body weight of the continually fed ones.

TABLE D

	Group	Control Animals (A)	Periodically Fasting Animals (C)	Ratio Between A and C ($A = 1$)
Number of feedings	i	120	60	1 ÷ 0.5
	ii	120	60	1 ÷ 0.5
	iii	120	60	1 ÷ 0.5
	iv	108	54	1 ÷ 0.5
Body weight (Initial wt. = 1 gr.)	i	4.395	2.520	1 ÷ 0.573
	ii	3.550	2.885	1 ÷ 0.813
	iii	3.520	2.490	1 ÷ 0.708
	iv	3.616	2.501	1 ÷ 0.692
Daily increase in body weight	i	0.028	0.025	1 ÷ 0.893
	ii	0.022	0.032	1 ÷ 1.455
	iii	0.021	0.025	1 ÷ 1.191
	iv	0.024	0.028	1 ÷ 1.167

Assuming the values for the normally fed animals equal to 1, we may sum up the results of our comparison of the growth in weight of continually fed individuals (*a*) and those starved (*b*) or intermittently fasting (*c*) in the following formulæ:

a	*b*	*c*	
1	0.5	0.5	Quantity of food.
1	2.01	1.18	Daily increase in weight.
1	1.01	0.70	Final body weight.

The results of the above study are obviously at variance with those of von Seland who found that his periodically fasting birds have been faring best. This difference in our results may, of course, be accounted for by the circumstance that the periods of fasting of my salamanders have been rather long (one to three weeks; also in Kahan's experiments the periods were from one and a half to two weeks) whereas von Seland's chickens have never fasted more than 12 to 48 hours at any time.

Why does the intermittent feeding produce such an inhibiting effect upon the growth of the body in weight? Before attempting to answer this question it should be recalled that these animals utilize a larger portion of their food in building up their tissues than normally fed salamanders do, the rate of their growth being likewise about one fifth greater. We also pointed out that the animals remained smaller in size and lighter in weight than the controls. We meet, thus, in the case of the periodically starved salamanders two contrary phenomena: on the one hand, we observed and directly measured on a number of individuals their deficient growth; on the other hand, we found that the growth activity has not been impaired, but even somewhat greater than in the case of the control Tritons. In the paper, already referred to in the beginning of this article, I showed that the water content of the organism increases 4 per cent. when salamanders are returned to a normal diet after protracted starvation. The water content probably comes back to the natural level when the animals have again reached their normal state. In the case of the intermittently fasting salamanders this may not happen, if the fast is repeated before the effect of the preceding inanition has been overcome. If we recall that the per cent. of water in the organism of starved individuals is also somewhat higher than the usual (by 1.5 per cent.) it becomes quite probable that water may be accumulating in the tissues of intermittently starved specimens to the extent of being a hindrance to their growth.

Acute hunger has an entirely different effect. It may even exhaust the organism for a time, but so long as degeneration has not set in—degenerative changes appear generally in the advanced stages of starvation—inanition may produce an invigorating influence upon the organism, which has its parallel in the embryonic growth only. The temporary relief which the organs of digestion get may contribute much towards improving their capacity, but the resulting rejuvenation of the organism is a composite effect of the activity of all its cells. The chief reason for the revitalization of the organism is in the enhanced need of the cells for nourishment. The cells become "avaricious," if we may say so, and the increased proportion of the nucleus in the cell organization may perhaps in a measure be responsible for that.

From all that has preceded the conclusion can be drawn that periodic starvation is more detrimental to the organism than acute starvation followed by a liberal supply of food. In the former case the individual remains below the level of the normally fed animals; in the latter case, on the contrary, provided the inanition has not been carried too far, the restorative process may go even beyond the limit attainable under normal conditions. From the viewpoint of practical application this conclusion is evidently of importance, suggesting to those who have made the problem of social welfare their own the dangers to the health and vigor of mankind which lurk in the more commonly occurring underfeeding and chronic starvation, especially of the young and growing generation.